Hydrogen Measurement Capabilities for Characterizing Hydrogen-Assisted Cracking in Dissimilar Metal Welds

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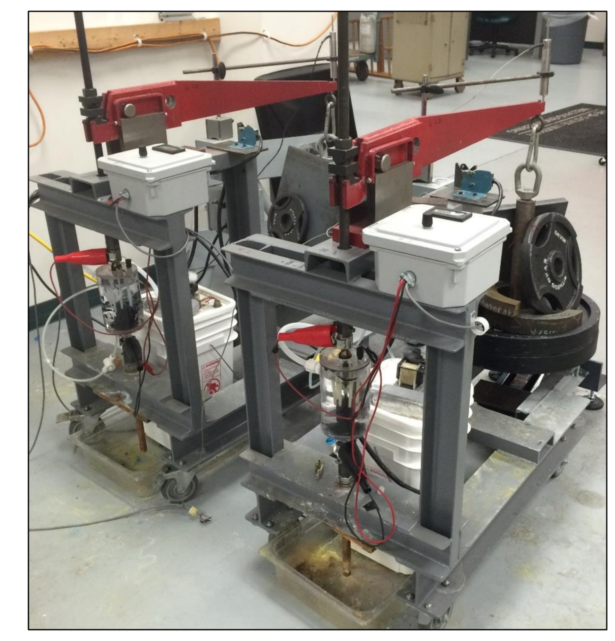
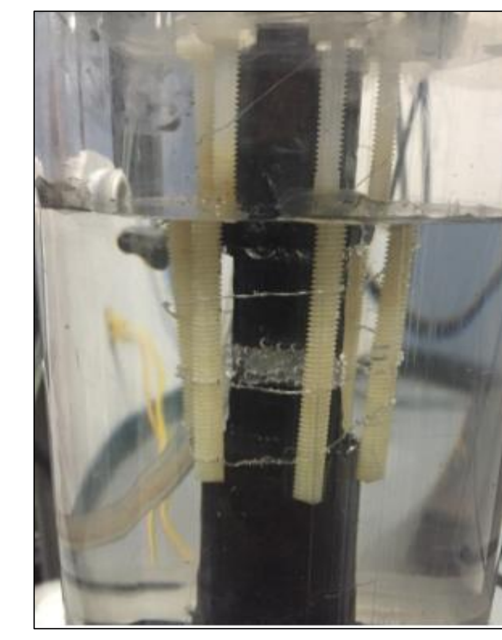
Background

- Oil and gas companies have been experiencing catastrophic subsea pipeline failures due to hydrogen assisted cracking (HAC)
- The cracking originates from dissimilar metal welds (DMWs) on high strength steel forgings with Ni-base or austenitic stainless steel filler metals after hydrogen slowly diffuses into the dissimilar transition zone in hydrogen containing environments
- The Welding Engineering Laboratory at The Ohio State University is currently conducting Delayed Hydrogen Cracking Tests (DHCT) on DMW samples to determine the conditions for failure utilizing constant loading conditions and simultaneous hydrogen charging



DHCT Test Stands



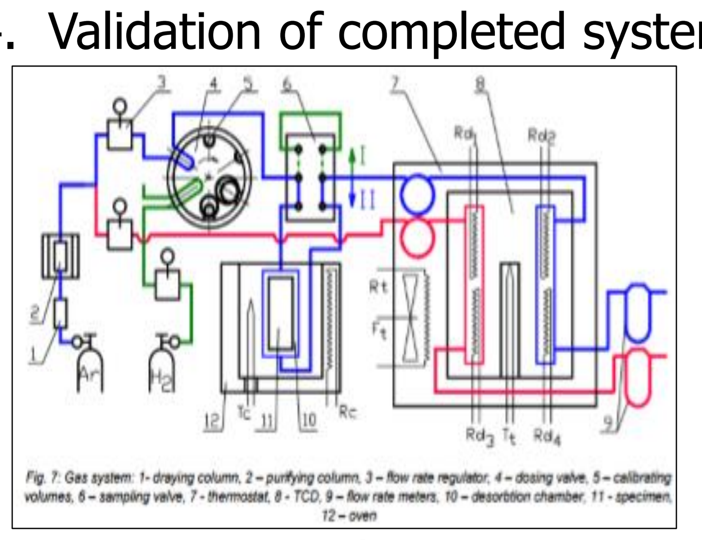
DHCT Sample

Motivation

- Additional hydrogen measurement capabilities were required to:
- Quantify the maximum amount of hydrogen, which diffuses into the sample before it fails in the DHCT test (hydrogen saturation time)
- Determine the rate at which hydrogen diffuses in and out of the sample (hydrogen diffusion coefficients)

Objectives & Approach

1. Modify existing gas chromatography thermal conductivity detector (GC TCD) to measure diffused hydrogen from DHCT test samples
2. Design new calibration method to supply exact volumes of hydrogen to the GC TCD system without leakage
3. Develop LabVIEW software to read, record, and analyze both the voltage and thermocouple signals from the device
4. Validation of completed system's accuracy with commercial systems



System Schematic

GC TCD System

Conclusions

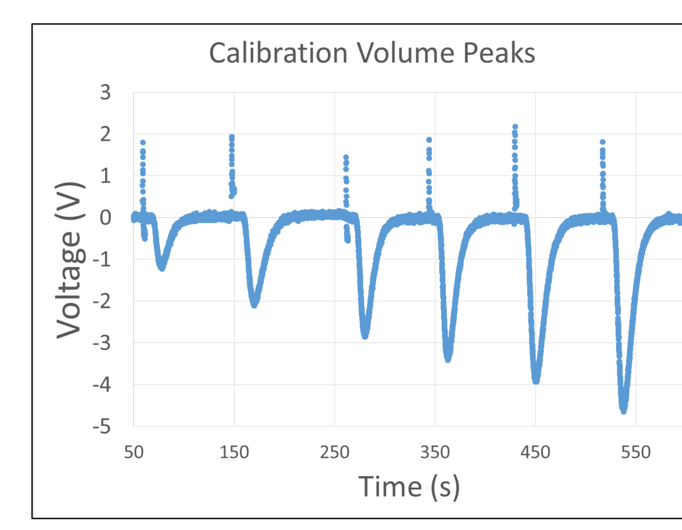
- Testing allows for hydrogen content and diffusion rate measurement from 5-100 mm³ for small metal and weld samples
- New calibration valve grants accurate TCD calibration utilizing small amounts of hydrogen.
- Invention disclosure has been filed for the calibration valve design with the OSU Office of Commercialization

Future Work

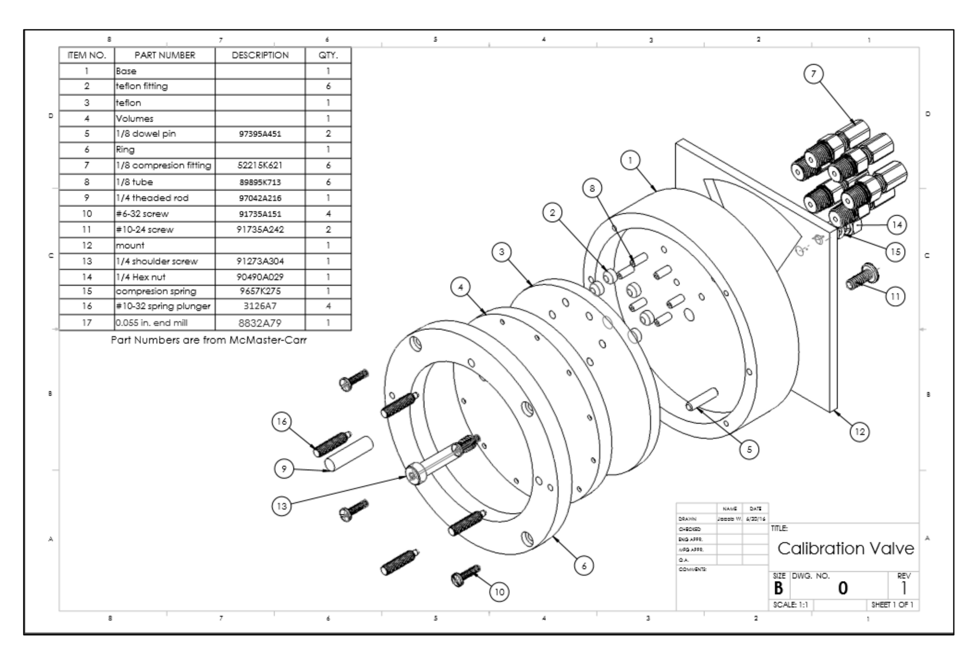
- Constructing a data base is of the hydrogen content and diffusion rates within DHCT samples of varying compositions, dimensions, and charging periods
- Applying the DHCT test with hydrogen measurement to prevent future failures by evaluation the HAC susceptibility of undersea pipes
- Validating GC TCD measurement results with commercial systems

Results & Discussion

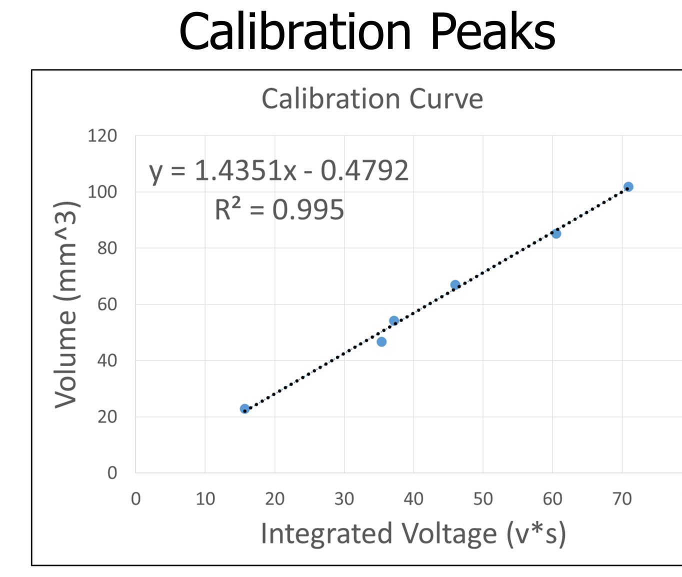
- The GC TCD functions by flowing nitrogen gas through a chamber containing a hydrogen charged sample, collecting the effused hydrogen and measuring its quantity in the TCD
- Each gas has a different coefficient of thermal conductivity; therefore, when the different gasses pass over the TCD they affect the temperature of the sensor proportionally and different voltage peaks are produced
- Utilizing a calibration valve with a newly invented design, the GC TCD calculates the volume of hydrogen within an unknown sample by comparing to signals from known volumes of hydrogen generated by the valve.



Calibration Peaks

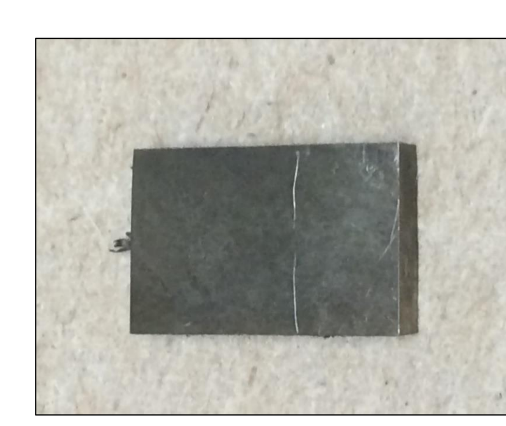


Calibration Valve Drawing

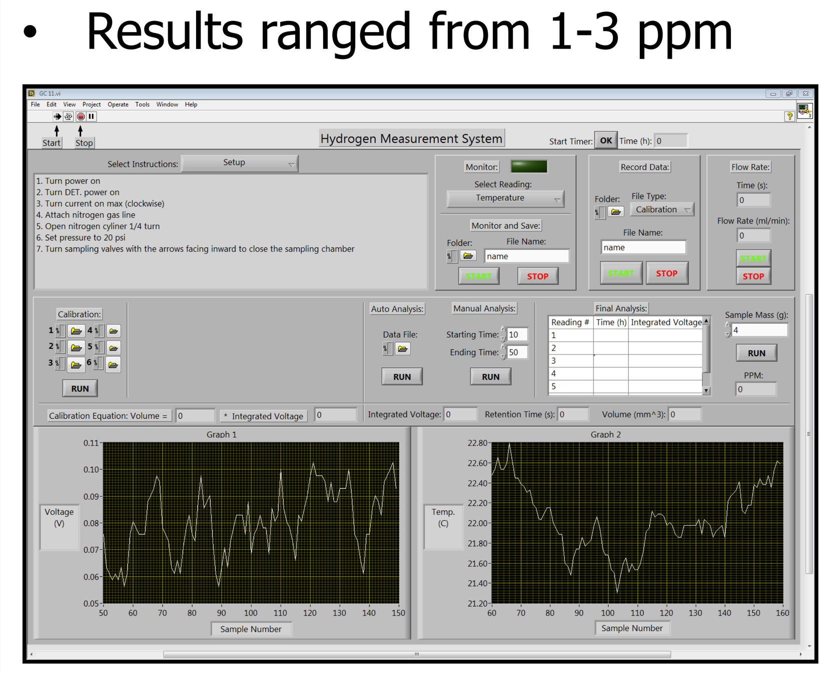


Calibration Equation

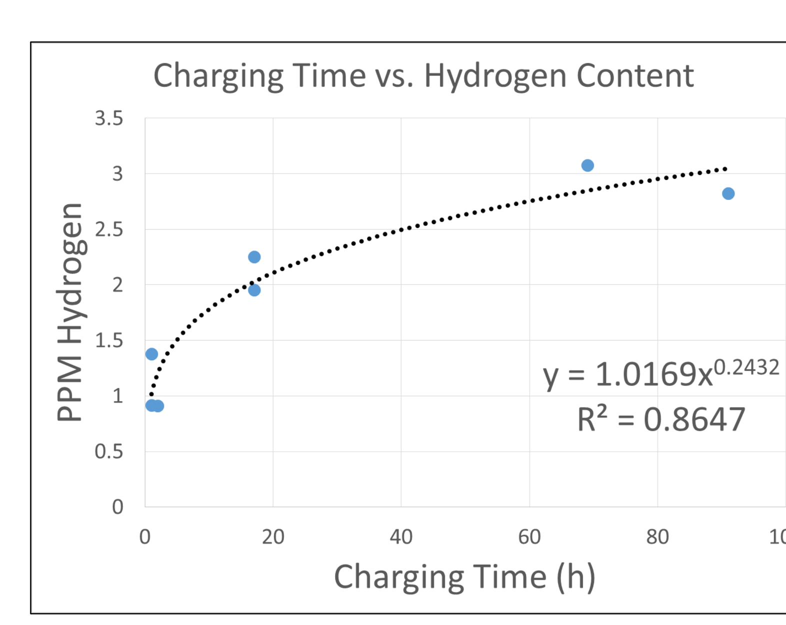
- LabVIEW software allows user to quickly calibrate the device and measure samples
- Hydrogen content is determined by utilizing a point by point integration method
- Preliminary tests included F22 samples charged with hydrogen for 1-91 hours
- Results ranged from 1-3 ppm



F22 Sample



Hydrogen Measurement System



Preliminary Test Results